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(54) **Preheating method of steel strips.**

(57) A method of preheating steel strips in continuous heat-treatment using a heating zone including radiant tubes comprises a combination of first and second preheating stages. In the first preheating stage, visible heat contained in burned waste gas from the heating zone is heat-exchanged with a gas to recover part of the visible heat into the gas which is directed to a steel strip. In the second preheating stage, a heat medium is heated in a heating device and supplied and circulated into rolls. The steel strip is wound about the rolls to pass thereon in a non-oxidizing atmosphere. In this manner, the steel strip is preheated progressively to higher temperature to achieve high temperature preheating without causing serpentine movement of the steel strip, thereby compacting the heating installation and improving the production efficiency.

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PREHEATING METHOD OF STEEL STRIPS

This invention relates to a pr heating meth d in continuous heat-treatment of steel strips for progressively heating the st el steel in plural stages to temperatures as near to those in a heating zon as possible.

A steel strip continuous heat-treating installation, for example, a steel strip continuous annealing installation comprises in usual a heating, soaking and cooling zone. A steel strip is heated to 650°C-850°C in the heating zone. As it is necessary to maintain a reducing atmosphere in the heating zone, radiant tube heating has been employed which, however, makes the installation of the heating zone complicated and large-sized. It is therefore important to preheat steel strips on an entry side of the heating zone in order to make the installation compact and improve the production efficiency.

Concerning the preheating on the entry side of the heating zone, Japanese Laid-open Patent Applications Nos. 57-41,330 and 58-73,727 disclose a method of preheating a steel strip in which visible heat of burned waste heat from a heating zone is recovered in heating medium by means of a heat exchanger and the heating medium is introduced into passages formed in rolls about which the steel strip is wound.

In this disclosed method, the visible heat of the burned waste heat at 300-350°C is recovered in the heating medium until the temperature becomes approximately 150°C in order to avoid a problem of dew point of oxygen, and thereafter the steel strip is preheated. In this manner, it is possible to preheat the steel strip to approximately 130-140°C to improve the recovery of waste heat.

In this case, however, the steel strip preheated to approximately 130-140°C is rapidly heated to 600-850°C by radiation heating mainly by radiant tubes. As such a heating has a limitation of heating speed, a huge installation is needed in order to increase the production. Moreover, as the preheating temperature is relatively low, it includes a possibility for more improving its thermal efficiency.

On the other hand, Japanese Laid-open Patent Application No. 57-76,133 discloses a heating method using rolls heated by induction heating coils without using the burned waste gas. This publication discloses an example of heating steel strips to 800°C using heated rolls at 1,000°C. Because of the great temperature difference between the steel strip and the rolls when the steel strip is wound about the rolls, there is a risk of serpentine movement of the steel strip caused by concave thermal crowns on the rolls due to temperature fall at outer peripheries of the rolls about which the steel strip is wound.

Even if the rolls are inherently provided with convex crowns in profile in order to stabilize the crown of the heating rolls, it is very difficult to maintain stable crowns because of variation in temperature of the steel strip passing about the rolls according to thickness of the steel strip in case of large temperature difference between the steel strip and heating rolls.

Moreover, it has been known that there is provided on an entry side of a heating zone a preheating furnace into which burned waste gas is directly introduced or there is provided on an entry side of a heating zone a non-oxidizing furnace for preheating steel strips (direct firing system). With the former, however, the burned waste gas directly contacts steel strips, so that there is a tendency for surfaces of strips to become worse due to oxidization of the surfaces and foreign substances (oxides, carbides and the like) in the waste gas attached on the surfaces. In the latter, the initial cost is increased.

Furthermore, Japanese Laid-open Patent Application No. 60-135,530 discloses a preheating method in which visible heat of burned waste gas from a heating zone is recovered in the air and the obtained hot air is directed onto steel strips to preheat them. In this method, however, the preheating temperature of the steel strip is at the most 100-200°C. It is impossible to obtain higher preheating temperature. When the temperature of preheated steel strips is within 100-200°C, bad configuration of the rolled steel strips is not straightened by such a low temperature preheating and maintained even when the steel strips are in an upstream half of a heating zone. In case that unevenness of the rolled steel strips are of the order of 1%, therefore, serpentine movements of the steel strips occur while being heated, so that feeding speed of the steel strips could not be increased resulting in lower production efficiency. The word "unevenness" is intended to mean a deviation of a steel strip from a complete flatness per a unit length.

It is a principal object of the invention to provide a method of preheating steel strips, which eliminates all the disadvantages of the prior art and which achieves the high temperature preheating by progressive preheating without causing serpentine movement of steel strips, thereby compacting the heating zone and improving the production efficiency.

In order to accomplish this object, the method of preheating steel strips in continuous heat-treatment using a heating zone including radiant tubes according to the invention comprises steps of directing onto a steel strip a gas including heat recovered in heat-exchanging from visible heat contained in burned waste gas from said heating zone to effect a first stage preheating, and winding said steel strip about heated rolls to pass on the rolls to effect a second stage preheating at higher temperature than that of the first stage preheating.

In a preferred embodiment, in case of using an oxidizing gas as the air in the first stage preheating, the temperature of the steel strip is maintained lower than a predetermined temperature by controlling amounts of the gas directed onto the steel strip in order to prevent formation of thick oxide films on the steel strip. The second stage preheating is preferably effected in a non-oxidizing atmosphere.

In another embodiment, a heat medium is h ated in a heat medium heating device and supplied and circulated int the rolls, thereby heating the rolls. The temperature of the steel strip is maintained lower than a

predetermined temperature by controlling at least one factor among flow rate and temperatur of the heat medium and winding angles of the steel strip about the rolls.

The invention will be mor fully understood by referring t th following detailed specification and claims tak n in connection with th appended drawings.

Fig. 1 is a schematic view illustrating a heating apparatus for explaining the method according to the invention;

Fig. 2 is a graph illustrating thermal effici ncy in comparison of th invention with conventi nal methods;

Fig. 3 is a graph illustrating fall in production efficiency in comparison of the invention with conventional method;

Fig. 4 is a graph illustrating the relation between the fall in production efficiency due to serpentine movement and the invention and conventional methods;

Fig. 5 is a graph illustrating serpentine movement in connection with temperature difference between heat medium and steel strip;

Fig. 6 is a graph illustrating the relation between thickness of oxide films and steel strip temperature;

Fig. 7 is a graph illustrating the relation between surface conditions and steel strip temperature;

Fig. 8 is a graph illustrating the relation between surface conditions and atmosphere in preheating zones; and

Fig. 9 is a graph illustrating the relation between steel strip temperature and investment and repayment indexes.

Referring to Fig. 1, illustrating one embodiment of the invention, a steel strip 1 is preheated to 100-200°C in a first preheating zone at a first preheating stage and to 250-250°C in a second preheating zone 3 at a second preheating stage.

First, burned waste gas is collected from a heating zone 4 including radiant tubes 5 into waste gas collecting ducts 6 and is introduced into a heat-exchanger 7 wherein visible heat of the waste gas is given to a gas such as the air while the waste gas whose temperature has been lowered is exhausted through a chimney 9 with the aid of a waste suction fan 8. The temperature of the waste gas is usually of the order of 400°C which is lower than those at which the fan and chimney can thermally resist.

The heated gas heated in the heat-exchanging (which is referred to hereinafter "hot blast") is circulated by a hot blast circulating fan 10 to be supplied into hot blast chambers 11 arranged in the first preheating zone 2, so that the hot blast is directed onto the steel strip to heat it to 100-200°C.

Other than the air, nitrogen, nitrogen mixed with hydrogen somewhat, or the like is suitable as the gas directed onto the steel strip in the first preheating zone 2.

On the other hand, a heat medium 12 in a reservoir 17 is heated in a heat medium heating device 13 and supplied and circulated into rolls 15 with the aid of a circulating pump 14. The heated medium 12 flows through the rolls 15 which are heated by the medium, so that the steel strip 1 from the first preheating zone 2 is wound about the rolls so as to pass through the second preheating zone 3 to heat the steel strip 1 to 250-500°C. The heat medium 12 which has heated the rolls is returned through a return line 16 into the reservoir 17.

The heat medium may be thermo-oil, metallic sodium, and a molten salt such as a nitrate as sodium nitrate, potassium nitrate or the like or a chloride as calcium chloride, sodium chloride or the like. The molten salt of the nitrate is preferable for preventing corrosion of the rolls.

A thermometer or thermometers 18 for the steel strip are provided on an exit side of the first preheating zone 2 to monitor whether the steel strip 1 is heated at temperatures between 100 and 200°C in the first preheating zone. If the temperature of the steel strip is higher than 250°C, thick oxide films are produced on surfaces of the steel strip to lower the quality of the surfaces. The amount of the hot blast directed onto the steel strip is controlled by adjusting numbers of revolution of the hot blast circulating fan 10 or provision of dampers in the lines in order to maintain the temperature of the preheated steel strip lower than 250°C.

Moreover, a thermometer or thermometers 19 for the steel strip are provided on an exit side of the second preheating zone 3 to monitor whether the temperature of the steel strip on the exit side of the second preheating zone 3 is maintained within 250-500°C while one or more of the flow rate and temperature of the heat medium 12 flowing into the rolls 15 and winding angles of the steel strip about the rolls are controlled.

Figs. 2-8 illustrate results of investigation of thermal efficiency, serpentine movement of steel strips, surface conditions and installation investment concerning the invention.

Experiments were carried out under the following conditions.

Steel strips : general cold rolled steel strips
Thickness of steel strips : 0.5-1.6 mm
Width of steel strips : 700-1,600 mm
Speed of steel strips passing through preheating zones : 100-300 m/min
Unevenness of steel strips on entry side of preheating zones : 0.5-1.5%
Tensile force in steel strips : 0.5-1.5 kg/mm^2

Rolls	Material	: stainless steel
	Outer diameter	: 500 mm, 1,000 mm, 1,500 mm
	Number of rolls	: 1-5

Steel strip temperature at entry side of the first preheating zone (heating by hot blast) : 40-60°C
Steel strip temperature at exit side of the first preheating zone : 100-200°C
Steel strip temperature at exit side of the second preheating zone (heating with rolls) : 250-500°C
Heat medium : chloride
Temperature of heat medium : 200-600°C

Fig. 2 and 3 illustrate thermal efficiencies in cases of the present invention, reference example A using only radiant tubes and reference example B using hot blast and radiant tubes.

As can be seen from Fig. 2, the thermal efficiency is greatly improved by effecting the second stage preheating with rolls mainly by the heat transmission between directly contacting metals.

Fig. 3 is a graph illustrating the fall in production efficiency due to serpentine movements of steel strips occurring before the heating zone when unevennesses of the steel strips are 0.5-1.0% before the heat treatment. This graph clearly shows the superiority of the present invention.

Fig. 4 illustrates the fall in production efficiency due to serpentine movements of steel strips similar to those in Fig. 3, in comparison with the reference example B. It is clear that the serpentine movements can be prevented by rapidly raising the temperature of the steel strips to the order of 500°C by preheating with rolls.

In Fig. 5, an abscissa indicates temperature difference between the heat medium and steel strips on the exit side of the second preheating zone and an ordinate indicates serpentine movement of steel strips per one heating roll. When the temperature difference is more than 300°C, the serpentine movements increase to an extent that the practical use is prohibitive. It is understood from this fact that the progressive heating with less temperature difference is suitable.

The reason why the large temperature difference increases the serpentine movements of the steel strips is as follows. When the temperature difference is large, center portions of the heating rolls are cooled more than edge portions of the rolls to increase concave crowns occurring on the heating rolls, so that the steel strips become unstable at the center portions of the rolls and tend to move to the edge portions owing to the usual tendency of the steel strips to move toward locations where tensile forces in the steel strips increase.

Fig. 6 illustrates the relation between thickness of oxide films and the temperature of steel strips on the exit side of the first preheating zone heating with hot blast. It is clearly evident that when the temperature of the steel strips is more than 250°C, the thickness of the oxide films increases. Even if the steel strips were reduced after preheating, the bad surface conditions of the steel strips could not be amended as shown in Fig. 7.

Fig. 7 illustrates observation of surfaces of steel strips which were subjected to the treatment for forming phosphate or chromium oxide films thereon after the continuous heat treatment and degreasing. An ordinate indicates the surface conditions of the strips.

Fig. 8 illustrates the surface condition of steel strips in case of the second preheating zone with the air or non-oxidizing atmosphere.

When the steel strips in the second preheating zone with the air were heated to 250-500°C, the oxide films became extremely thick. Even after reducing the steel strips in the heating zone, uneven oxide films remained on the surfaces under the bad surface treated condition.

As seen from Fig. 9, when the temperature of the steel strips on the exit side of the first preheating zone were higher than 200°C, both investment index and repayment year index became higher. In other words, installations such as hot blast circulating fans, motors, heat-exchangers and the like are enlarged to increase both the invenstment and repayment year.

Moreover, the quantity of heat and flow rate of the respective gases when the temperature of the steel strips on the exit side of the heating zone became 750°C are as follows under the same conditions as those above described.

Burned gas in radiant tubes in the heating zone	:	15×10^6 Kcal/h
		6,500 Nm^3/h
Heat-up gas from a burning furnace for heating a heat medium	:	4×10^6 Kcal/h
		22,000 Nm^3/h

Visible heat of the heat-up gas was given through a heat-exchanger to the air to be used in the first preheating zone, so that the temperature of the heat-up gas dropped from 600°C to 350°C.

On the other hand, the amount of the air circulating through the first preheating zone was 80,000 Nm/h. The quantity of heat of 2×10^6 Kcal/h was obtained by heat-exchanging. In this case, the air temperature was 250°C on an entry side of the heat-exchanger and 330°C on an exit side thereof.

Example

Steel strips were heated by means of the heating apparatus shown in Fig. 1 under the following conditions.

(I) The first preheating zone

Thickness of steel strips	:	0.6-1.0 mm
Width of steel strips	:	900-1,200 mm
Speed of steel strips passing through preheating zone	:	200-300 m/min
Heating length in the first preheating zone	:	50 m
Amount of circulating hot blast	:	80,000 Nm^3/h (at 200°C)
Pressure of directed hot blast	:	50-70 mm H_2O
Directed hot blast temperature	:	250-350°C
Heat transfer coefficient	:	60 $Kcal/m^2h \cdot °C$

Table 1 shows the temperatures of steel strips on the exit side of the first preheating zone.

Table 1

Steel strip	Thickness (mm)	0.6	0.7	0.8	0.9	1.0
	Width (mm)	900	1,000	1,200	1,000	1,200
Passing speed of steel strip (m/min)		300	280	250	300	200
Temperature of steel strip (°C)		160	150	170	100	200

(II) The second preheating zone

Heat medium : nitrate

Temperature of heat medium : 500°C

Heat transmission coefficient between steel strips and heat medium : 1,000-1,500 Kcal/m^2h·°C

Number of rolls : 4

Diameter of rolls : 1500 mm

Winding angle of strips about rolls : 120°

Under above conditions, when steel strips of 0.8 mm thickness were heated at passing speed of 200 m/min, the steel strips at 200°C on the entry side were heated to 350°C on the exit side.

This invention performs the preheating steel strips to higher temperatures preventing serpentine movements of the steel strips, thereby improving the production efficiency and compacting the installation.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details can be made therein without departing from the spirit and scope of the invention.

Claims

1. A method of preheating steel strips in continuous heat-treatment using a heating zone including radiant tubes, comprising steps of directing onto a steel strip a gas including heat recovered in heat-exchanging from visible heat contained in burned waste gas from said heating zone to effect a first stage preheating, and winding said steel strip about heated rolls to pass on the rolls to effect a second stage preheating at higher temperature than that of the first stage preheating.

2. A method of preheating steel strips as set forth in claim 1, wherein in case of using an oxidizing gas as the air in the first stage preheating, the temperature of the steel strip is maintained lower than a predetermined temperature by controlling amounts of the gas directed onto the steel strip on order to prevent formation of thick oxide films on the steel strip.

3. A method of preheating steel strips as set forth in claim 1, wherein the second stage preheating is effected in a non-oxidizing atmosphere.

4. A method of preheating steel strips as set forth in claim 1, wherein a heat medium is h ated in a heat medium heating device and supplied and circulated into said rolls, thereby heating the rolls.

5. A meth d of preheating steel strips as set forth in claim 4, wherein said heat medium is a substance

selected from a group including a thermo-oil, metallic sodium, and a molten salt such as a nitrate as sodium nitrate and potassium nitrate and a chloride as calcium chloride and sodium chloride.

6. A method f preheating steel strips as set forth in claim 4, wherein the temperature of the steel strip is maintained lower than a predetermined temperature by controlling at least one factor among flow rate and temperature of said heat medium and winding angles of the steel strip about said rolls.

FIG_1

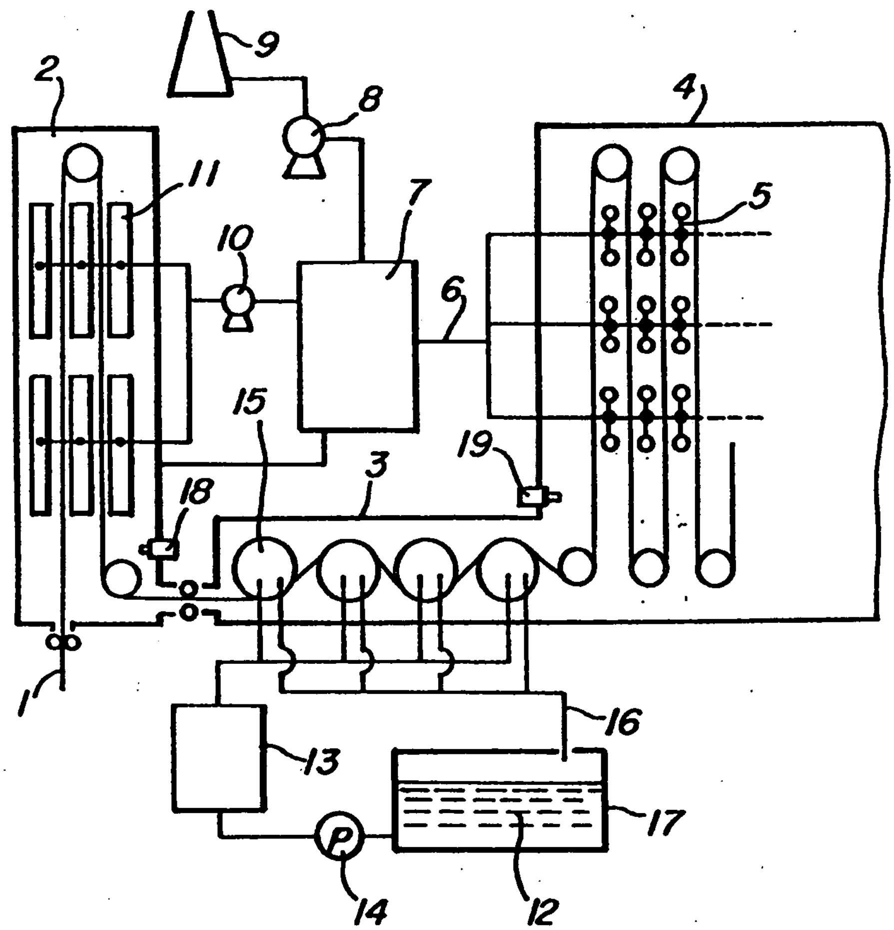


FIG_2

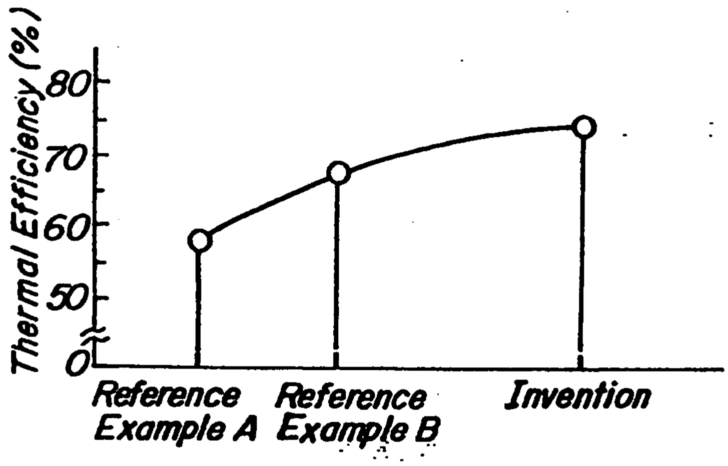

Thermal Efficiency (%)
80
70
60
50
0
Reference Example A
Reference Example B
Invention

FIG_3

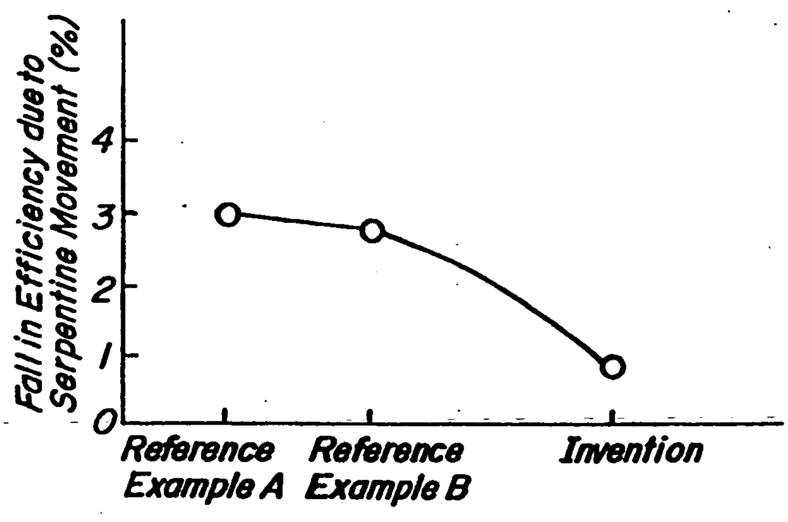

Fall in Efficiency due to Serpentine Movement (%)
4
3
2
1
0
Reference Example A
Reference Example B
Invention

FIG_4

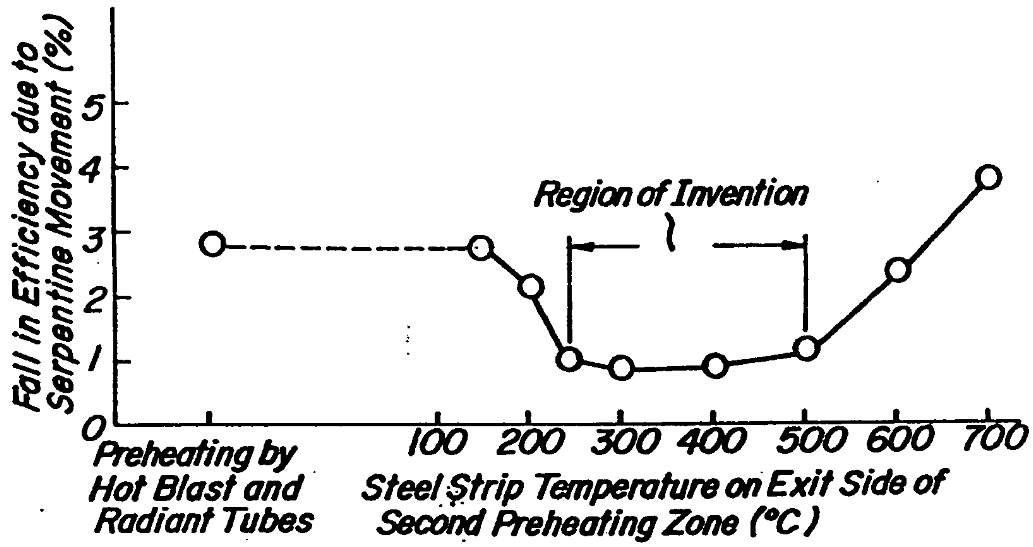

Fall in Efficiency due to Serpentine Movement (%)
0
1
2
3
4
5
Region of Invention
l
Preheating by Hot Blast and Radiant Tubes
100 200 300 400 500 600 700
Steel Strip Temperature on Exit Side of Second Preheating Zone (°C)

FIG_5

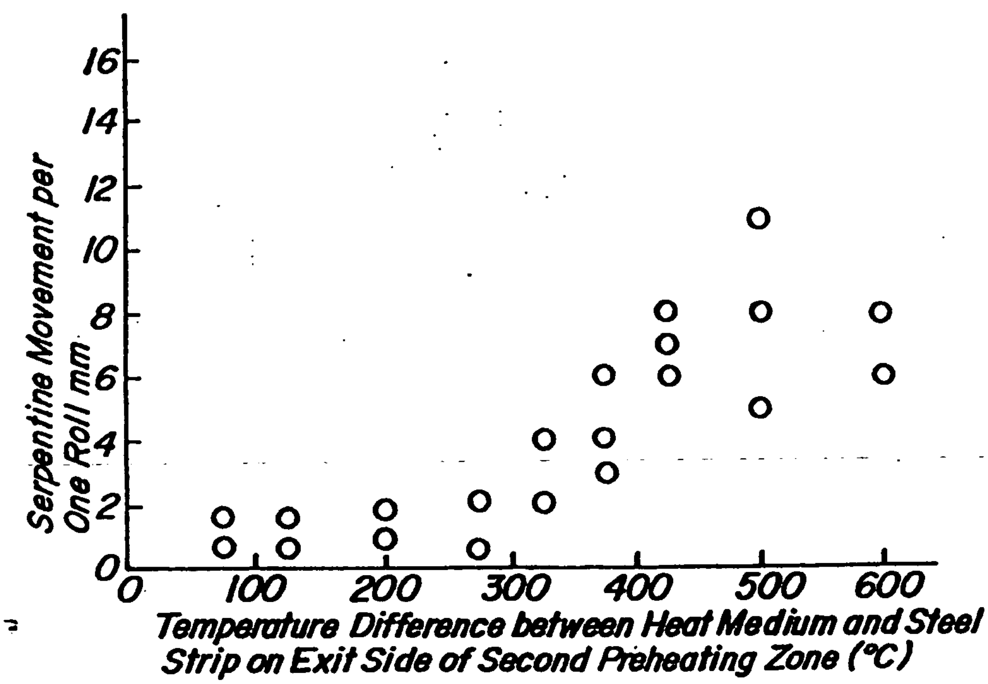

Serpentine Movement per One Roll mm
0
2
4
6
8
10
12
14
16
0 100 200 300 400 500 600
Temperature Difference between Heat Medium and Steel Strip on Exit Side of Second Preheating Zone (°C)

FIG. 6

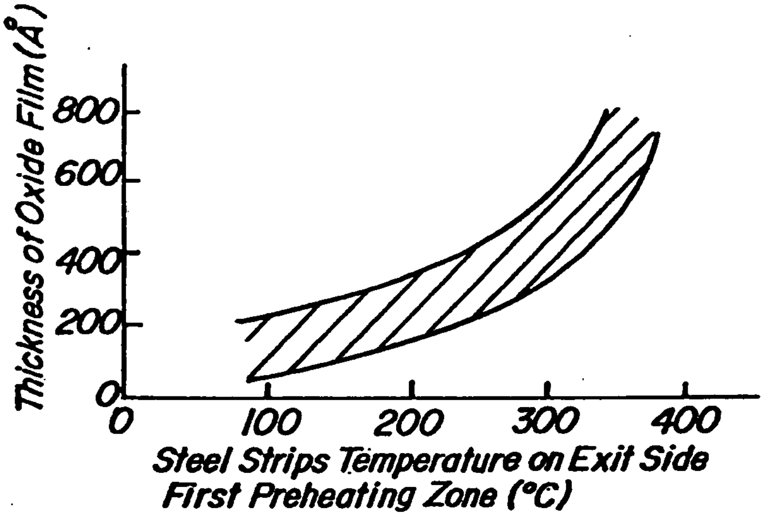

Thickness of Oxide Film (Å)
800
600
400
200
0
0
100
200
300
400
Steel Strips Temperature on Exit Side
First Preheating Zone (°C)

FIG. 7

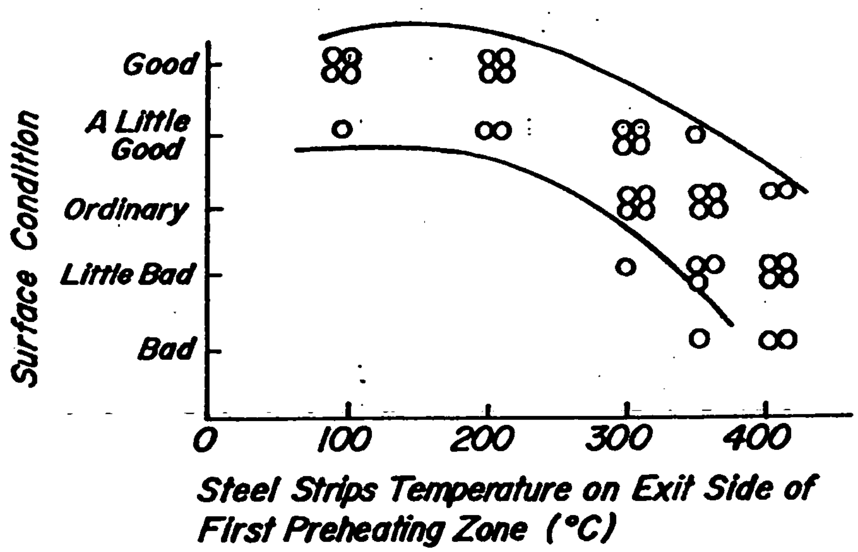

Surface Condition
Good
A Little Good
Ordinary
Little Bad
Bad
0
100
200
300
400
Steel Strips Temperature on Exit Side of
First Preheating Zone (°C)

FIG_8

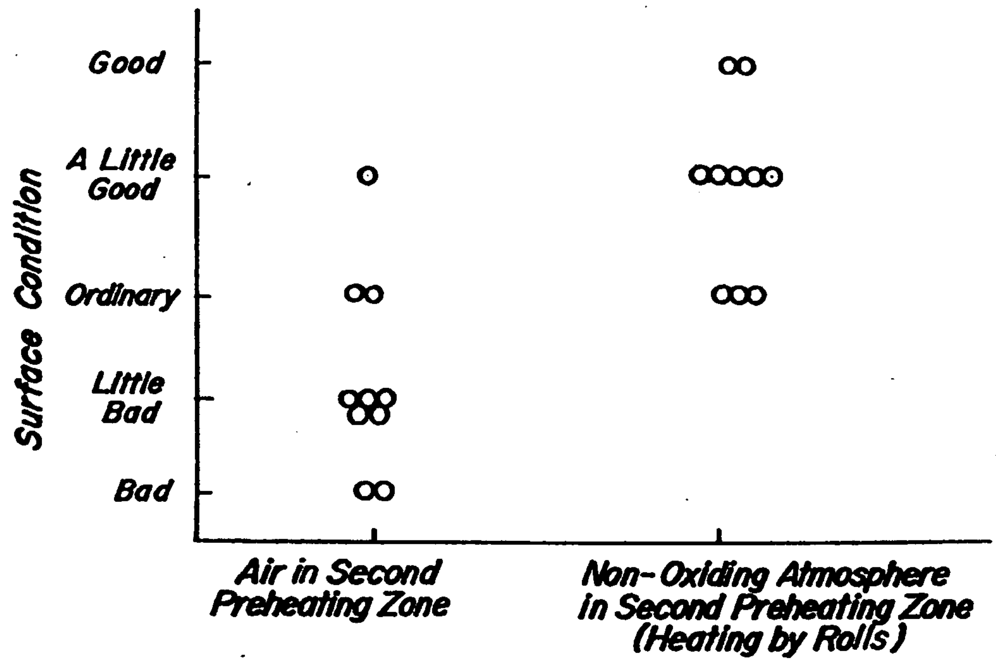
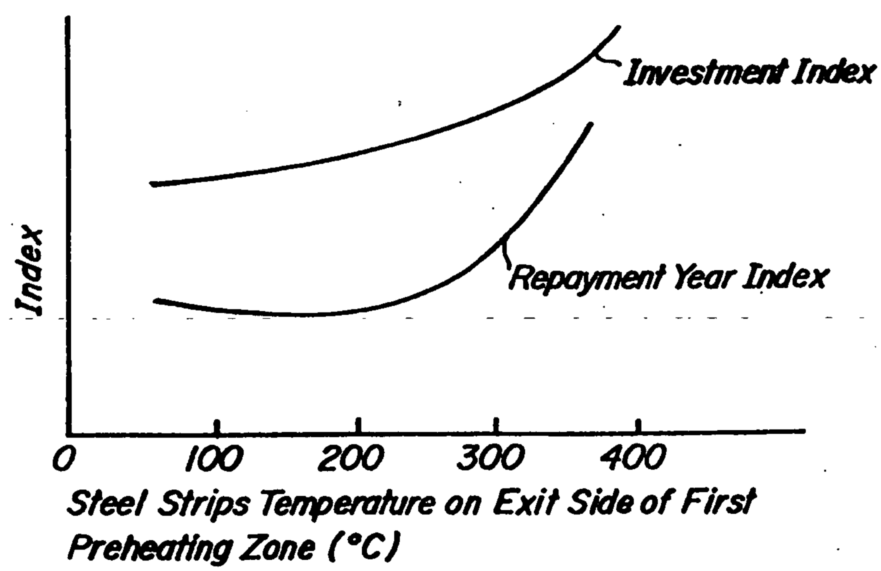

Surface Condition
Good
A Little Good
Ordinary
Little Bad
Bad
Air in Second Preheating Zone
Non-Oxiding Atmosphere in Second Preheating Zone (Heating by Rolls)

FIG_9


Index
Investment Index
Repayment Year Index
0
100
200
300
400
Steel Strips Temperature on Exit Side of First Preheating Zone (°C)